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RESTORING NATIVE GRASSES AS VEGETATIVE BUFFERS IN A COASTAL CALIFORNIA AGRICULTURAL LANDSCAPE

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ABSTRACT

We investigated changes in vegetation composition of different grass buffer strips in a fragmented coastal agricultural landscape to evaluate the potential for native grass restoration of sites that receive agricultural runoff. Vegetative buffers bordering Elkhorn Slough, draining into Monterey Bay, California, were either seeded with a non-native annual grass (*Hordeum vulgare*) or with a mix of native perennial grasses (*Bromus carinatus*, *Deschampsia cespitosa*, *Nassella pulchra*), and aboveground biomass and cover of vegetation were measured over a 4-yr period. Based on preliminary results, we initiated a second, smaller-scale experiment to test establishment of native perennial grasses (*Bromus carinatus*, *Elymus glaucus*, *Hordeum brachyantherum*) at different seeding densities with combinations of non-native annual grasses (*H. vulgare* or *Lolium multiflorum* and *Vulpia myuros*) to optimize erosion control.

In the first experiment, plots seeded with non-native annual grasses had greater biomass than native perennial plots in the first year. Biomass and cover of seeded annual grass decreased each year, which resulted in these plots being dominated by unseeded non-native species by the third year. In contrast, seeded native perennial grasses increased in both biomass and cover by the second year, with little cover of non-native species; but, in the third year cover of non-native species increased. By the fourth year, unseeded non-native species provided nearly all plant biomass and cover in all treatments. In the second experiment, native perennial grass cover was low, but was greater when seeded alone compared to when seeded with non-native annuals. The seeded annual grass *V. myuros* invaded and provided the majority of cover in most plots by the second year. Our results suggest that some species of native perennial grass can establish on former agricultural lands, but long-term survival is difficult without extensive management.

Key Words: *Bromus carinatus*, *Deschampsia cespitosa*, exotic invasion, *Nassella pulchra*, native grass restoration, vegetative buffer strips.

Restoring native grasslands in California has become a conservation priority (Bugg et al. 1997; Hatch et al. 1999; Corbin et al. 2004). In a recent review, Hoekstra et al. (2005) identify temperate grasslands and Mediterranean ecosystems, as the two most threatened biomes globally, where habitat area converted to human uses is more than eight times the area protected. The remaining grasslands in California are dominated by non-native annual species from other regions with similar climatic conditions (Bartolome et al. 1986; Huenneke 1989; Corbin et al. 2004). Along the California coast, potential sites for grassland restoration are limited and are often embedded in a matrix of agricultural lands.

Increasingly restoration efforts are motivated not only by efforts to conserve biodiversity, but also to provide ecosystem services, such as erosion control and water purification (Holl and Howarth 2000; Aronson et al. 2007). Determining whether restoration projects can meet these multiple targets is critical, particularly as funding is often linked to demonstrating benefits to humans through valued ecosystem services (Holl and Howarth 2000). An example of restoration projects potentially meeting multiple goals is restoration of vegetative buffer strips (VBS), which are strips of land between agricultural lands and nearby waterways.

Past research has demonstrated that VBS improve water quality in many temperate agricultural landscapes, by removing excess nitrogen and suspended sediments from agricultural runoff before they enter surface waters (Schlosser and Karr 1981; Dillaha et al. 1989; Muscutt et al. 1993; Daniels and Gilliam 1996). However, there has been little study of restoring native species in buffer strips, particularly in Mediterranean climates, where rainfall is highly episodic.

Native grass restoration on sites receiving high nutrient input from agricultural lands may prove to be particularly challenging. Many studies have shown that nutrient enrichment, specifically N, alters competitive interactions between species and results in increased productivity, favoring intro-

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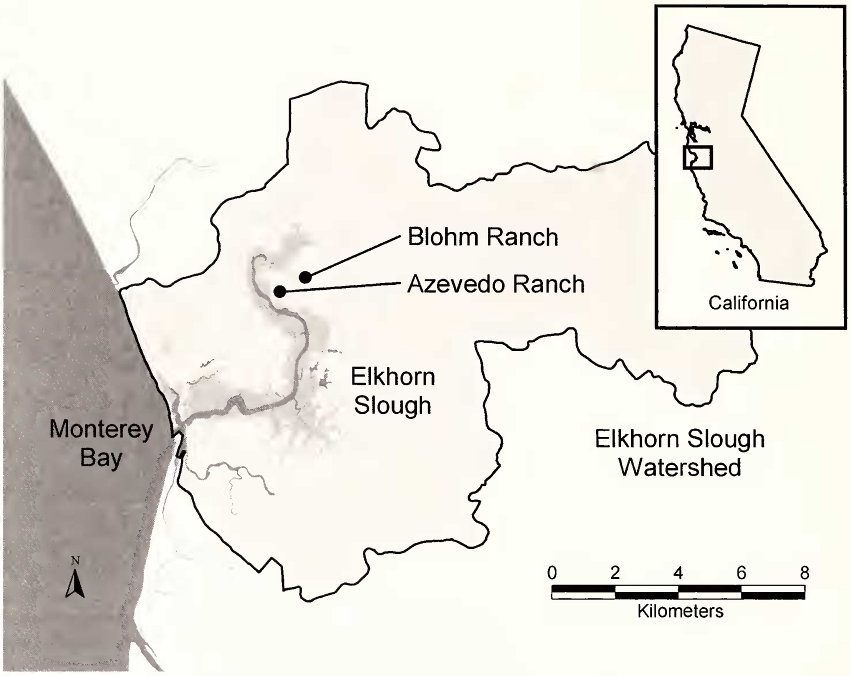

FIG. 1. Regional map of study area showing watershed boundary and study sites.

duced annual grasses (e.g., Inouye and Tilman 1995; Dyer and Rice 1997; Jeffries and Maron 1997; Hooper and Vitousek 1998; Weiss 1999).

Through two studies, we investigated the feasibility of restoring native grasses in vegetative buffer strips receiving runoff from conventional row crops along the central coast of California. At the first site, we compared plots seeded with native perennial grasses and plots seeded with a non-native annual grass commonly used for erosion control. At the second site, we evaluated if different seeding mixes and densities of native perennial grasses and non-native annual grasses could provide both short- and longer-term cover.

METHODS

Study Sites

This study was conducted in the Elkhorn Slough watershed, a major coastal wetland draining into the Monterey Bay National Marine Sanctuary (Fig. 1). The surrounding uplands have steep slopes and sandy loam topsoil, and are particularly susceptible to erosion (USDA 1984). Approximately 26% of the watershed is in agricultural production (USDA 1994). High sediment and N concentrations in agricultural runoff enter and degrade the estuary (USDA 1984; Rein 1999a; Caffrey 2002). Non-native vegetative buffers have been recommended for erosion control (USDA 1984, 1994).

The first study was conducted adjacent to and downslope from row crops on Azevedo Ranch in the Elkhorn Slough watershed (Fig. 1). The study was conducted on a 1.2 ha portion of the ranch with a slope ranging from 12–22%. At the top of the slope is a flat upper terrace, where farm activities continued. This slope drains into a salt marsh connected to Elkhorn Slough. Prior to the study, strawberries were grown on both the slope and the terrace, with rows extending to the edge of the marsh. Beginning in July 1995, crop production was limited to the terrace, and the 1.2-ha slope was used for this study. The Azevedo study was conducted over the following period: September 1995–September 1996 (first year), 1996–1997 (second year), 1997–1998 (third year) and 1998–1999 (fourth year). The years correspond to agricultural and rainfall years, rather than calendar years. During these four years, strawberries were grown in the first year and flowers (*Delphinium* sp.) cultivated in the second, third, and fourth years.

A second experiment was established in September 1997 (the third year of the Azevedo study) at Blohm Ranch, which is located approximately 1 km up-slope from Azevedo Ranch (Fig. 1). Blohm Ranch was taken out of agricultural production in 1996; therefore only residual agricultural fertilizers rather than an ongoing input contributed to surface and subsurface runoff during the study period. The site has an average slope gradient of 20–25%.

The soils on both the study sites are Arnold loamy sand and Elkhorn fine sand (USDA 1979). Soils (0–15 cm) were 11–20% clay, 7–25% silt, 64–73% sand, and dry bulk density was 1.2 g cm^{-3}. Although classified as similar soils, the Azevedo soils are finer textured than the loamy sands of the Arnold series on the Blohm ranch. There is a shallow clay horizon located within 50 cm from the surface at Blohm Ranch, while Azevedo has a deeper clay layer ranging from 1–6 m below the surface.

The local Mediterranean climate is characterized by an extended dry season (May–September) and episodic rain storm events primarily between November and April. Rainfall varied substantially among the years of the study in both total quantity and intensity, with annual rainfall above the 20-yr average for the watershed (450 mm) in all years of the study (USDA 1994). Annual rainfall ranged from 587 mm yr^{-1} to 761 mm yr^{-1} during the study period and was highest in the El Niño year of 1997–1998, as measured at a California Irrigation and Management Information Station 7 km from the study area (DWR 2005).

Azevedo Ranch Experimental Design

Six plots (40 m × 20–39 m) were created along the topographic fall line. The plots were located down-slope from and received surface and sub-surface water flow from the row-crop agriculture. Each plot was assigned to one of two treatments in a randomized complete block design: (1) native perennial grasses (a mix of *Bromus carinatus* (California brome), *Deschampsia cespitosa* (tufted hairgrass), and *Nassella pulchra* (purple needlegrass); or (2) non-native annual grass, 100% *Hordeum vulgare* (common barley). Nomenclature follows Hickman (1993), and a full species list is available from the authors. Perennial grass seeds were purchased from the Elkhorn Native Plant Nursery (Moss Landing, CA), with seeds collected within the watershed. *Hordeum vulgare* was selected because it is used as a cover crop and to control erosion; seed was purchased from General Feed and Seed (Santa Cruz, CA). Unseeded plants in all plots established from seeds dispersed from adjacent lands and the seed bank.

Azevedo Ranch Site Management

At Azevedo Ranch, the soil was disked in September 1995, and then irrigated. Emergent weeds were disked in once, prior to seeding the plots in October 1995, in an effort to reduce the weed seed bank. Grass seeds were hand broadcast and buried by disking to a depth of 15–20 cm, and irrigated once in November 1995 to increase seed germination before the onset of rains. Seeding rates were *N. pulchra*—85 seeds m^{-2}, *B. carinatus*—210 seeds m^{-2}, *D. cespitosa*—1000 seeds m^{-2} and *H. vulgare*—600 seeds m^{-2}, based on recommended rates for disking seeds in for erosion control (P. Kephart, Director, Rana Creek Ranch).

Non-native annual grass plots were re-seeded by hand broadcasting in November 1996 and October 1997 to ensure re-establishment. Non-native annual grass plots were mowed to a height of 10–15 cm after *H. vulgare* senescence in June 1996 and May 1997, pursuant to the farmer's concern about birds perching on the grass stalks and consuming strawberries.

Azevedo Ranch Vegetation Sampling

In February 1996, February 1997, April 1997, April 1998, and May 1999, species composition, percent cover and above-ground biomass were measured in three 30 × 30 cm quadrats randomly located along three transects at 5, 20, and 40 m from the upper plot boundary (9 quadrats total). In the final year, cover was recorded in six quadrats (two per transect) and biomass was only recorded in two quadrats, as there were few to no target species in the plots.

Cover was estimated visually to the nearest percent (Dethier et al. 1993). Above-ground biomass was clipped, dried at 60°C, and weighed to the nearest 0.1 g. Harvested plants were separated into two groups: species seeded in a plot (*H. vulgare* or native perennial grass) and non-seeded species (including species that were seeded in another treatment and spread).

Blohm Ranch Experimental Design

The treatment area was subdivided into four blocks, each with seven 5 × 5 m plots. Each plot was assigned to one of seven treatments with different seeding densities of three seed mixes: (1) native perennial mix (*Bromus carinatus*, *Elymus glaucus* (blue wildrye) and *Hordeum brachyantherum* (meadow barley)); (2) *Hordeum vulgare*; and (3) *Lolium multiflorum* (Italian ryegrass) and *Vulpia myuros* (Zorro fescue). The seven treatments (Table 1) included seeding each species mix individually, as well as seeding 50% and 75% proportions of the two non-native annual mixes with 50% and 25% native perennials to determine if the annuals would provide short-term cover while allowing for long-term establishment of native perennial grasses.

Species and seeding rates (Table 1) were selected based on results of the initial study, local plant experts, typical erosion control practices, and site-specific conditions (J. Fodor, Central Coast Wilds, and P. Kephart, Rana Creek Ranch, personal communications). At the time of the study, the National Resource Conservation Services (NRCS) widely recommended a mix of *L. multiflorum* and *V. myuros* for erosion control in this region (R. Caselle and D. Mountjoy, NRCS personal communication). *H. vulgare* was

TABLE 1. SEEDING TREATMENTS AT BLOHM RANCH.

Treatment name	Composition	Seeding Rate (kg/h)[1]
Native perennial grass mix (Per)	33% *Elymus glaucus*	3
	33% *Hordeum brachyantherum*	3
	33% *Bromus carinatus*	3
Hordeum vulgare (Hv)	100% *Hordeum vulgare*	43
Lolium multiflorium/Vulpia myuros (Lm/Vm)	50% *Lolium multiflorum*	3
	50% *Vulpia myuros*	3
High density perennial with *H. vulgare* (Per-High-*Hv*)	50% *H. vulgare*	21.5
	50% native perennial grass mix	1.5 (each)
High density perennial with *L. multiflorum/V. myuros* (Per-High-*Lm/Vm*)	50% *L. multiflorum/ V. myuros*	1.5 (each)
	50% native perennial grass mix	1.5 (each)
Low density perennial with *H. vulgare* (Per-Low-*Hv*)	75% *H. vulgare*	32.3
	25% native perennial grass mix	0.75 (each)
Low density perennial with *L. multiflorum/V. myuros* (Per-Low-*Lm/Vm*)	75% *L. multiflorum/ V. myuros*	2.25 (each)
	25% native perennial grass mix	0.75 (each)

[1] Differences in seeding rates reflected differences in seed weight.

selected because farmers commonly use it as a cover crop, and it established rapidly in the main study. All seeds, except *H. brachyantherum*, were provided by the NRCS. *H. brachyantherum* seeds were purchased from Central Coast Wilds (Santa Cruz, CA).

The soil was disked and level planed in September 1997. Grass seeds were hand broadcast and buried by disking. A 1-m strip between plots was seeded with *V. myuros*. The field surrounding the study plots was hydroseeded by the land manager with an erosion control mix consisting of *B. carinatus*, *H. vulgare*, *Trifolium hirtum*, and *V. myuros*.

Blohm Ranch Vegetation Sampling

Plant cover and biomass were measured at Blohm Ranch using the same procedures as at Azevedo Ranch. Vegetation cover and biomass were sampled in one 30 × 30 cm quadrat per plot; quadrats clipped in the previous year were not resampled. Vegetation was sampled in April 1998 and May 1999, the first and second years after seeding. Harvested plants were separated into seeded species (Table 1) and volunteers (species not seeded) for biomass measurements.

Statistical Analyses

We analyzed all data using SAS software version 8.1 (SAS Institute, Inc., Cary, NC). Biomass and cover data were analyzed using a t-test for Azevedo and a one-way ANOVA for Blohm with vegetation treatment as the independent variable, and data from each year analyzed separately. Data were log-transformed (biomass) or arcsin-transformed (cover) when necessary. The multiple vegetation quadrats per plot at Azevedo were averaged prior to statistical analysis. If treatment was found to be significant in the ANOVA, then Tukey's multiple comparison procedure was used to test differences between treatments.

RESULTS

Azevedo Ranch

In the first year, biomass of the native perennial grass mix was lower than in the annual grass treatment (Fig. 2A; $t = 5.0$, $P = 0.007$). By the second year, however, native perennial grass biomass was significantly greater than the annual grass treatment (Feb.: $t = 9.2$, $P < 0.001$, Apr.: $t = 4.1$, $P = 0.015$). Cover of seeded species in the first two years showed similar trends to biomass, except that unseeded species had higher relative cover than biomass, resulting in no significant treatment differences in total cover (Fig. 2B; $t < 2.0$; $P >> 0.05$ in all cases). In the third year, native perennial grasses remained dominant but *H. vulgare* did not re-establish well, and both cover and biomass in the annual grass treatment was dominated by unseeded species (Fig. 2). By year four, nearly all cover in both treatments was comprised of unseeded species with no difference in cover ($t = 2.6$, $P = 0.234$). Similarly, biomass was 99% unseeded species.

Of the three native perennial grass species seeded, *B. carinatus* comprised >90% of native perennial grass cover with <5% cover of the other two species. None of the seeded species established substantially outside their seeded area. Cover of the few species of native volunteers, such as *Anaphalis margaritacea*, *Lotus scoparius*, and *Lupinus bicolor*, totaled less than 5% in any given year. The relative abundance of non-native volunteers changed over time. Averaged across all treatments, *Poa annua* (6%) and the annual forbs *Erodium botrys* (9%) and *Trifolium hirtum* (6%) were the most abundant in the first year, but their cover decreased in subsequent

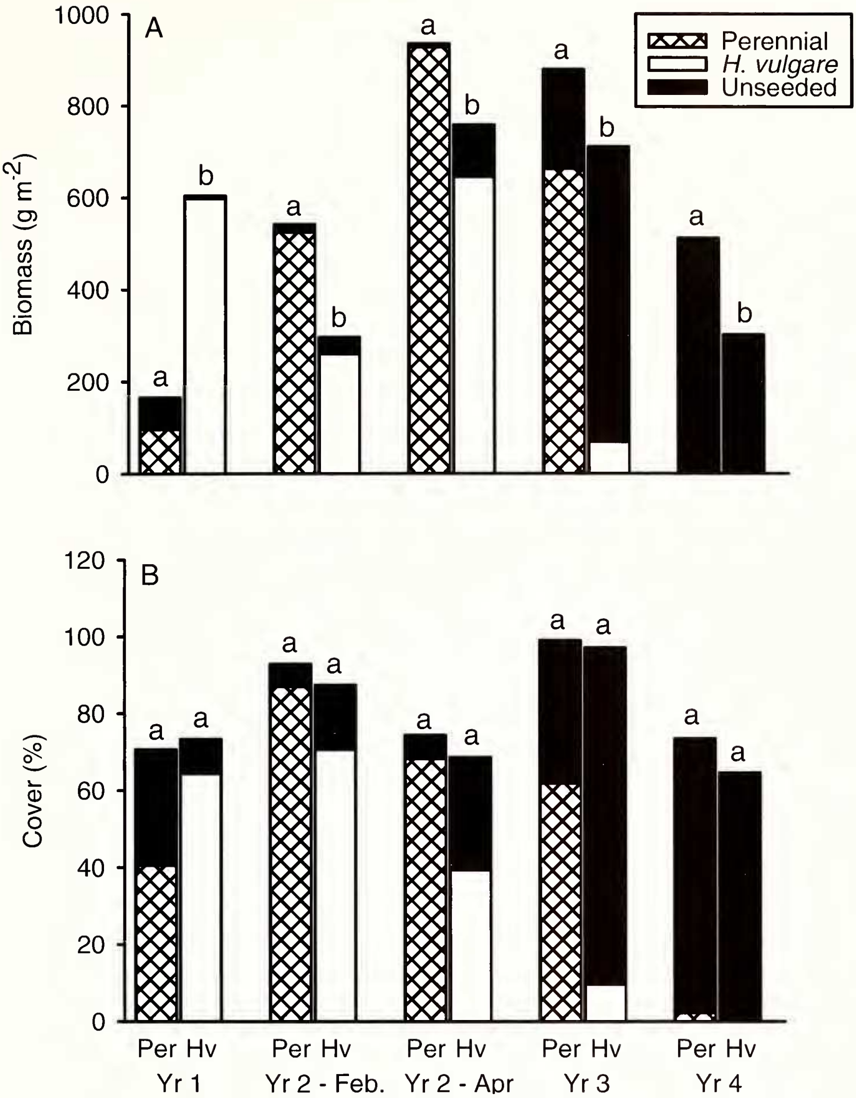

FIG. 2. Vegetation biomass (A) and cover (B) in perennial grass (P) or annual grass *Hordeum vulgare* (*Hv*) treatments at Azevedo Ranch over four years. Shading indicates composition of vegetation: seeded native perennial grasses, seeded exotic annual *H. vulgare*, or unseeded, volunteer species. n = 3 for all treatments. Treatments with the same letter do not have significantly different total biomass or cover.

years. The N-fixer, *Medicago polymorpha*, had high cover in the second (10%) and third (32%) years. Non-native plants in the Asteraceae family (*Picris echioides*, *Conyza canadensis*, and *Senecio* sp.) established in the first year and became increasingly important over time. By the third year, these species, along with *Epilobium* spp., were dominant. Several grass species, such as *Vulpia myuros* (15%) and *Lolium multiflorum* (9%), replaced the forbs by the fourth year.

Blohm Ranch

Native perennial grass cover at Blohm Ranch was low in both years compared to Azevedo, but was significantly greater in plots seeded with 100% native perennial grasses (Fig. 3B; 1998: $F = 3.7$, $P = 0.012$; 1999: $F = 16.1$, $P < 0.001$). In the first year, total biomass and cover, comprised primarily by unseeded species, in particular *Medicago polymorpha*, were similarly high across treatments (Fig. 3; $F < 1$, $P >> 0.05$ in both cases). By the second year, *V. myuros*, and a much smaller amount of *L. multiflorum*, comprised a similarly large percentage of the cover in all treatments (27–57%; Fig. 3; $F = 0.88$, $P = 0.529$), whereas cover of *H. vulgare* was nearly non-existent (<1%). In year 2, total biomass was considerably lower due to reduced biomass of unseeded species. Again, total biomass and cover did not differ significantly by treatment (Fig. 3; $F < 1$, $P >> 0.05$ in all cases).

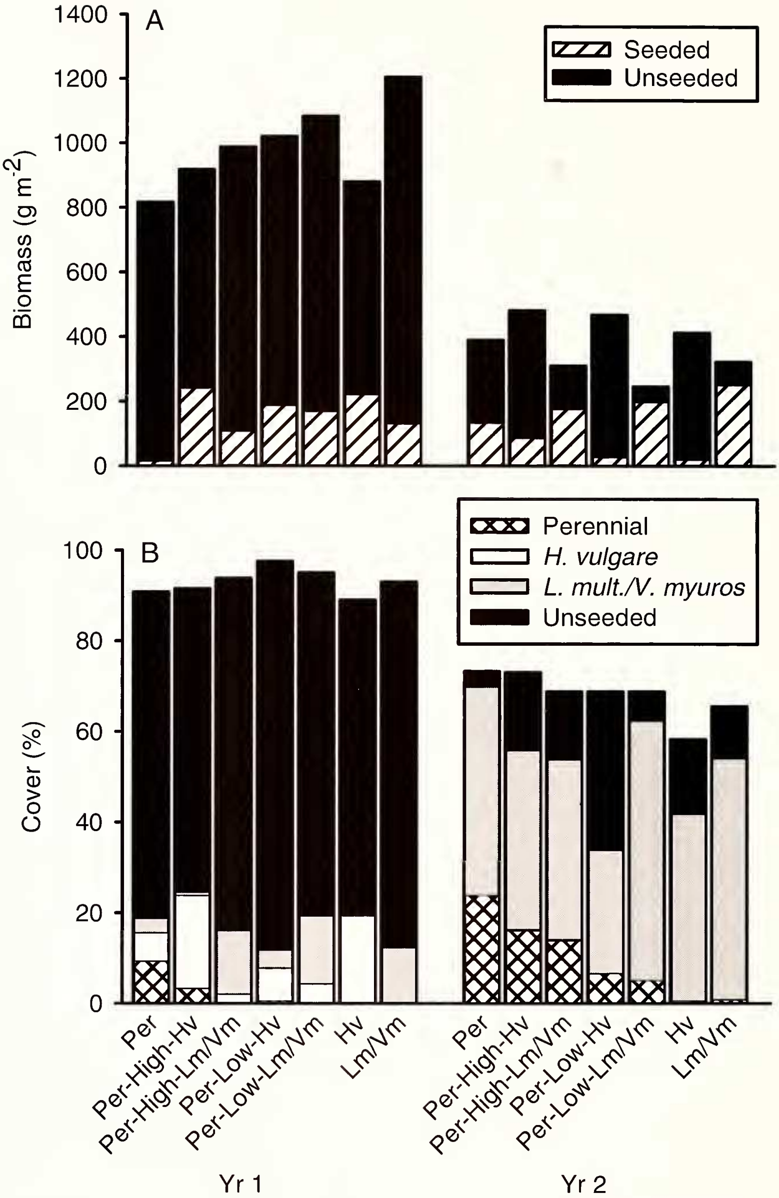

FIG. 3. Vegetation biomass (A) and cover (B) at Blohm Ranch. Shading indicates vegetation composition. See Table 1 for full treatment descriptions. Biomass is separated into species that were seeded into a specific treatment (seeded) and those which were not seeded into that treatment (unseeded). Cover was separated into native perennial grasses (perennial), *Hordeum vulgare* (*Hv*), *Lolium multiflorum* and *Vulpia myuros* (*Lm*/*Vm*), and species not seeded into a treatment (unseeded).

Of the native perennial grasses, *H. brachyantherum* had the highest proportion of cover (63%) with substantial cover of *B. carinatus* (30%) and lower cover of *Elymus glaucus* (7%). Like at Azevedo, cover of native volunteers was less than 5%. In the first year, most plots were colonized by *Medicago polymorpha* (51%) and *Trifolium hirtum* (19%); by the second year, however, each of these species covered less than one percent averaged across all plots. In 1999, the same non-native Asteraceae as at Azevedo (2%), the annual non-native forb *Erodium botrys* (4%), and the native *Lotus scoparius* (3%) were among the most abundant.

DISCUSSION

The goal of this research was to determine the feasibility of restoring native perennial grasses in vegetative buffer strips in an agricultural landscape in coastal California, while simultaneously providing sufficient cover to minimize erosion and prevent agricultural sediments from entering into nearby water bodies. The results of our two studies indicate that: 1) perennials do not establish rapidly in the first year which makes the sites vulnerable to initial erosion and non-native invasion; 2) perennials establish higher cover by the second year; 3) perennial grasses can establish when seeded in combination with annuals, but their cover is lower and some common erosion control species (e.g., *Vulpia myuros*) may themselves be invasive; and 4) over the long-term it will be challenging to maintain perennial grasses in sites with high nutrient and non-native seeds inputs without extensive ongoing management.

Vegetation Establishment

The potential to use areas adjacent to agriculture to restore native habitat and effectively reduce agricultural sources of pollution in a Mediterranean climate depends on the rapid establishment of vegetative cover. In both our experiments, the seeded non-native annuals established more dense cover and biomass in the first year than the native perennial grasses. This result is consistent with other restoration projects and studies comparing annual and perennial plant growth rates (e.g., Anderson 1993; Garnier and Vancaeyzeele 1994; Corbin and D'Antonio 2004), particularly in high nutrient environments (Classen and Marler 1998).

By the second year, perennial grass biomass was more than five times higher at both sites and provided a similar amount of erosion control as the annual treatment at Azevedo (Rein 1999b). Our results, as well as several other studies in California, show that native perennial grasses can successfully establish in an agricultural environment (Anderson 1993; Stromberg and Kephart 1996; Bugg et al. 1997; Seabloom et al. 2003; Corbin and D'Antonio 2004).

At both sites, *Bromus carinatus* established well, and *Hordeum brachyantherum* provided substantial cover at Blohm Ranch. *Deschampsia cespitosa* comprised less than 5% of the native perennial cover throughout the study at Azevedo. *D. cespitosa* has small seeds and may have been buried too deeply when initially disked in, accounting for the low establishment success. *Nassella pulchra* also had low cover, although it has been successfully reintroduced in other restoration studies (Corbin and D'Antonio 2004; Fehmi et al. 2004). It may not have established well since it is sensitive to low light levels and may have been shaded out by *B. carinatus* (Dyer and Rice 1997, 1999). Stromberg and Kephart (1996) similarly note that *B. carinatus* had much higher cover than *N. pulchra* in the first few years in other restoration projects in the region.

Seeding Mixes of Annual and Perennial Grasses

It is difficult to conclude whether mixed seeding of non-invasive annual grasses, such as *H. vulgare*, and perennial grasses is a suitable strategy for restoring native grasses and providing erosion control, given that overall establishment of both annual and perennial grasses was quite low in all treatments, compared to at Azevedo. This lower establishment likely resulted from a number of factors. First, less effort was made at Blohm Ranch to exhaust the weed seed bank and the plots were much smaller, likely increasing the abundance of unseeded species, in the first year. Second, the hardpan at Blohm Ranch created a different moisture regime than at Azevedo. Third, Blohm ranch was not irrigated prior to the rainy season so some seed may have washed off in early storms. Fourth, nearby agricultural activities had ceased by the time of the study at Blohm Ranch, so ongoing inputs of N were likely substantially lower than at Azevedo. These different results highlight the importance of testing restoration treatments at multiple sites before making general management recommendations and tailoring restoration strategies to site conditions (Anderson 1993; Stromberg and Kephart 1996).

Results from the Blohm Ranch study concur with previous research showing that *V. myuros* is highly invasive and may suppress perennial grasses (Brown and Rice 2000); therefore, its use in proximity to native grass restoration projects is not advisable. In our study at Azevedo, none of the native perennial grasses nor the *H. vulgare* established noticeably outside their seeded area. In contrast, at Blohm Ranch, *V. myuros* spread across the entire test site. A total of five species was included in the mix drill-seeded across the surrounding areas, yet only *V. myuros* dominated the site by the second year (Rein personal observation).

Resisting Invasion

Restoring native grasslands requires not only initial establishment of native species, but also the ability to resist invasion by non-native plant species over the long-term. After the second year at Azevedo native grass restoration appeared successful, yet by the fourth year there were few native perennial grasses remaining. Restoration projects often are evaluated after two or three years and monitoring may not continue. In restoration sites, species composition is often dynamic, especially on post-agricultural land (Inouye and Tilman 1995; Muller et al. 1998), necessitating the need for ongoing monitoring and management (Anderson 1993; Stromberg and Kephart 1996).

Due to the high nutrient input from agricultural runoff at Azevedo, it is not surprising that the non-natives invaded all treatments. Nutrient enrichment usually favors non-native species, including annual grasses (D'Antonio and Vitousek 1992; Inouye and Tilman 1995; Jeffries and Maron 1997; Hooper and Vitousek 1998; but see Seabloom et al. 2003; Thomsen et al. 2006). Furthermore, as vegetative buffers occur in fragmented and often disturbed habitats, non-native seed sources are abundant.

Although many studies have shown that perennial grasses in California are limited by competition with non-native species (e.g., Dyer and Rice 1997, 1999; Fehmi et al. 2004; Buisson et al. 2006), some studies have found that the native perennial grasses are able to outcompete non-natives over time (Corbin and D'Antonio 2004) and even reinvade annual grass stands if seeded (Seabloom et al. 2003). These contrasting results are probably due to a variation of past agricultural history, soil nutrients, non-native control efforts, and species studied (Anderson 1993; Stromberg and Griffin 1996; Seabloom et al. 2003). In particular, we made substantially less effort to control non-native species prior to and during the experiment than restoration practitioners recommend (Anderson 1993; Stromberg and Kephart 1996), in part due to concerns about using herbicides immediately adjacent to a National Estuarine Research Reserve.

The dominant native species in the Azevedo study *Bromus carinatus*, has received relatively little study compared to *Nassella pulchra*. Seabloom et al. (2005) likewise showed that it decreases in cover within a few years after seeding, which may be one reason for the low resistance of our restoration treatment to invasion. Differences in responses among perennial grass species, highlight the problems with generalizing conclusions about vegetation dynamics of all native grasses based on studies of one or two species, as species may respond quite differently to varying site conditions and disturbance regimes (Bugg et al. 1997; Hayes and Holl 2003; Bartolome et al. 2004; Thomsen et al. 2006). In particular, the vast majority of past grassland restoration in California has been done on inland grasslands and the results of coastal studies are often quite different (Corbin and D'Antonio 2004).

In conclusion, restoring native grasslands in a highly fragmented agricultural landscape with ongoing nutrient inputs and extensive non-native seed sources will be challenging and resource intensive. It will require careful species selection and further testing over multiple years to determine whether species, such as *N. pulchra*, which have been demonstrated to resist invasion in small experimental studies, are able to do so in an active agricultural landscape. It also will require intensive ongoing management, such as well-timed burning, grazing, or mowing (Hatch et al. 1999; Dyer 2003) to favor native grass species, or herbiciding to control aggressive non-native species (Anderson 1993; Stromberg and Kephart 1996; Corbin et al. 2004).

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